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ASSESSMENT OF SHALLOW DRILLING GEOHAZARDS FOR SAFE WELL PLACEMENT FROM SEISMIC DATA IN THE TANO BASIN, OFFSHORE GHANA

Prosper Aduah Akaba[1*], Raymond Dogbevia Eli[1], Solomon S.R. Gidigasu[1], Kwame Sarkodie[2], Frederick K. Bempong[3], Cyril Ofori Kupualor[1], Jerry Dogbevia-Greenfields[4], Gordon Foli[1]

[1]Department of Geological Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[2]Department of Petroleum Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[3]Department of Petroleum Geosciences and Engineering, University of Mines and Technology, Tarkwa, Ghana.
[4]Department of Geophysics, Ghana National Petroleum Corporation (GNPC), Tema, Ghana

***Corresponding author: paakaba.coe@knust.edu.gh**

ABSTRACT

The increasing global demand for oil and gas underscores the need for comprehensive assessments of geohazards in offshore drilling operations to ensure safety and efficiency. This study investigates shallow drilling hazards in the Tano Basin, offshore Ghana, focusing on geologic structures and conditions that pose risks to well placement. Utilising high-resolution 3D seismic data, seabed features and subsurface horizons were mapped, and structural depth analyses were performed to evaluate potential drilling risks. The study identified a northwest trending canyon with steep flanks prone to sliding or rotation, posing a risk to wellbore stability. Faults were prevalent in Unit B, with significant gas accumulations associated with an unconformity at Horizon 1. This unconformity serves as a potential trap for gas, elevating the risk of blowouts during drilling activities. Minor gas accumulations were also detected between Horizons 1 and 2, indicating drilling hazards. Key recommendations include avoiding well placements near seabed canyons, fault zones, and areas with gas accumulations. These regions are susceptible to mass movements, explosions, and structural instability, which could compromise drilling operations. The findings emphasise the critical role of seismic data analyses in identifying geohazards and guiding safe and cost-effective drilling strategies. By providing insights into seabed morphology and shallow subsurface geology, this study contributes to mitigating risks and enhancing the safety of offshore petroleum exploration within Tano Basin.

Keywords: Geohazards; Offshore Petroleum Exploration; Seismic Data Analysis; Well Placement; Tano Basin

INTRODUCTION

Background

The global demand for oil and gas continues to rise, driven by population growth, industrialization, and expanding energy needs. Offshore basins have become critical to meeting these demands, but exploration and drilling activities are inherently risky due to geohazards such as shallow gas accumlation, faults, and unstable seabed conditions, which can lead to catastrophic failures.

The 2010 Deepwater Horizon disaster exemplifies the consequences of unmitigated geohazards. An explosion released approximately four million barrels of oil into the Gulf of Mexico, resulting in extensive ecological damage and loss of life (Offshore Technology, 2019). Such incidents highlight the necessity of comprehensive geohazard assessments to ensure safety and environmental protection in offshore drilling.

Geohazards in offshore environments often stem from unique geological and geomorphological conditions, including over-steepened slopes, seabed canyons, and fault zones, destabilizing drilling operations (Giles & Griffiths, 2020). These risks necessitate the development of robust geohazard assessments that incorporate detailed analyses of seabed morphology, subsurface geology and fault dynamics.

The Tano Basin, located offshore Ghana, is a prolific hydrocarbon province with significant exploration potential (Atta-Peters, 2014). However, its complex tectonic history, including episodes of rifting, transform faulting, and sedimentation, presents challenges that pose offshore exploration risks. Addressing these hazards is essential for developing safe and cost-effective drilling strategies.

This study aims to assess shallow drilling hazards in the Tano Basin, offshore Ghana, to identify safe locations for well placement and enhance drilling safety. This involves a comprehensive evaluation of geological features and conditions that pose potential risks during drilling operations. The specific objectives were:

- Analysing seabed morphology: Mapping seabed features to identify potential hazards such as canyons and unstable slopes (Chiocci *et al*., 2011; Strasser *et al*., 2011)
- Investigating shallow subsurface geology: Evaluating geological units and their susceptibility to hazards like gas accumulations and faults (Malehmir *et al*., 2016)
- Assessing wellbore stability risks: Identifying geological structures that may compromise wellbore integrity (Bowes & Procter, 1997; Chen *et al*., 2002; McLellan, 1996; Mohiuddin *et al*., 2001).

Geological Setting

The Tano Basin, located along the West African Transform Margin (Rüpke *et al*., 2010), is bounded by the Ivory Coast Basin to the west and the Saltpond Basin to the east (Delteil et al 1974: Brownfield and Charpentier, 2006). Its geological evolution is marked by phases of continental rifting and transform faulting, resulting in complex tectonic and sedimentary features that present both opportunities and challenges for hydrocarbon exploration(Mark *et al*., 2018.) .

The basin's development began during the Late Jurassic epoch with the initiation of continental rifting, which progressed into the formation of oceanic crust during the Early Cretaceous. This rifting was accompanied by the deposition of clastic sediments derived from the African continent (Bempong *et al*., 2019). Notably, the tectonic evolution of the Tano Basin has been influenced by three major WSW-ENE Fracture Zones: the St. Paul's, Romanche, and Chain Fracture Zones (Tetteh, 2016). These tectonic structures have shaped the basin's morphology, creating potential geohazard zones such as faults, unstable slopes and gas accumulations.

The sedimentary architecture of the basin is characterized by sequences of sandstones, shales and carbonates, with significant unconformities marking periods of tectonic activity and erosion. One such unconformity, the Oligocene-Miocene boundary, is associated with shallow gas accumulations that pose risks to drilling operations (Fuentes, 2019). Additionally, the basin's seabed features include canyons and over-steepened slopes, particularly in the northern and eastern regions, which are prone to mass movements (Strasser *et al*., 2011).

Understanding the geological setting of the Tano Basin is essential for identifying the geohazards that could impact well placement. The combination of active tectonics, sedimentary deposition, and seabed morphology creates a complex environment requiring detailed seismic analysis to ensure safe and effective offshore drilling.

Offshore Geohazards

Offshore geohazards refer to geomorphological and geological features that pose risks to drilling operations, infrastructure stability, and environmental safety (Ercilla *et al*., 2021). These hazards can lead to catastrophic failures and are particularly significant in hydrocarbon-rich basins, where geological features such as shallow gas accumulations, fault zones and unstable seabed conditions often disrupt operations (Kvalstad, 2007).

In the Tano Basin, the primary offshore geohazards include:

- **Shallow Gas Accumulations**: Localized pockets of gas, often trapped in unconformities, increase the risk of blowouts during drilling (Liu *et al*., 2022). The Oligocene-Miocene unconformity identified in this study serves as a key horizon for such accumulations (Rossetti *et al*., 2013).

- **Fault Zones**: Numerous faults, intersect critical horizons and compromise wellbore stability. These faults can act as conduits for gas migration, amplifying risks associated with shallow gas (Machado, 2020).

- **Seabed Canyons and Steep Slopes**: Features like the north-south trending seabed canyon with steep flanks increase the potential for mass movements and sediment instability. These hazards are concentrated in the eastern and northern portions of the basin (Chiocci *et al*., 2011).

- **Polygonal Fault Networks**: Deeper intersecting fault systems create complexities, including risks of wellbore instability and drilling fluid loss (Ercilla *et al*., 2021).

Studies in similar offshore basins have demonstrated that seismic attribute analysis—such as trace envelope and dip similarity—effectively identifies and maps these hazards (Machado, 2020). These findings emphasise the importance of tailored geohazard assessments, as the distribution and intensity of hazards in the Tano Basin are shaped by its unique tectonic and sedimentary history. For example, while features like gas chimneys and shallow gas accumulations are common in the Gulf of Guinea, the Tano Basin's steep seabed slopes and active fault systems pose additional challenges for well placement (Delteil *et al,* 1974).

This study builds upon the growing body of literature on offshore geohazards (Cox *et al*., 2020a; Ercilla *et al*., 2021; Kvalstad, 2007), focusing specifically on the Tano Basin. By leveraging high-resolution 3D seismic data, it aims to delineate hazards such as shallow gas pockets, faulted zones, and unstable seabed features. These findings will provide actionable insights to guide safe well placement and minimise risks during offshore exploration activities.

MATERIALS AND METHODS

Study Area and Data Acquisition

The study was conducted in the Tano Basin, offshore Ghana, a geologically complex region along the West African Transform Margin. The basin is characterized by active tectonics, steep seabed gradients, and shallow gas accumulations, making it a key focus for geohazard assessments to guide safe drilling practices. High-resolution 3D seismic data, provided by Springfield Exploration and Production Limited and shot by Petroleum Geo-Services, were used for this study. The dataset was depth-converted (Cox *et al*., 2020b; Herron, 2013) using reliable time-to-depth conversion charts derived from wells in the study area. Figure 1 shows broadly the standard industry practice hence the process adopted for this study (Fuentes, 2019).

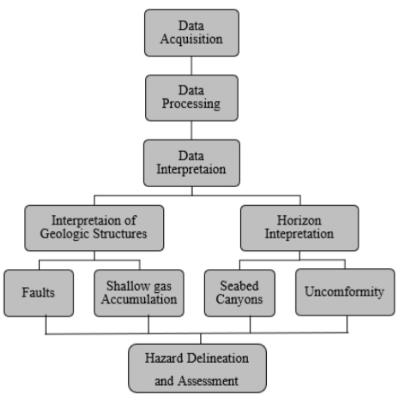

Figure 1: Flow chart of processes adopted for the research

The seismic survey covered approximately 148.687 km² with the following specifications:

- Vertical Sampling Rate: 5 m
- Inline Spacing: 18.75 m (oriented north to south)
- Crossline Spacing: 12.5 m (oriented east to west)
- Dominant Frequency: ~48 Hz

These specifications resulted in:

- Seabed depth range: - 463 m (north) to -1,242 m (southwest)
- Seabed gradients: typically, 3° to 14°, occasionally up to 45° on canyon flanks

Data Processing

Seismic data were analysed using the IHS Kingdom software, employing standard industry techniques for interpretation and attribute analysis. According to Cox et al. (2020b); Herron (2013); Rijks & Jauffred (1991) and Taner & Sheriff (1977), the processing workflow should include:

Data Loading and Quality Control

- Loading data in depth mode for accurate subsurface mapping
- Quality assessment to ensure data were free from significant artefacts
- Verification of higher frequency content preservation due to shallow investigation depths

Horizon and Fault Mapping

- Implementation of regular grid interpretation
- Interpretation spacing: 5 for both inlines and crosslines (10 for seafloor)
- Total interpretation length: 11.7768×10^6 m
- Square loop mapping to prevent miss-ties
- Auto-tracking validation performed in sections for quality control

Grid Interpolation

- Automated filling of mapped grid spaces using auto-tracking tools
- Manual validation of interpolated results
- Specific interpolation for horizons H2 and H1 due to surface irregularities

Geological and Geohazard Assessment

The assessment focused on three primary units:

- Unit A: Seabed to Horizon H1
- Unit B: Horizon H1 to Horizon H2
- Unit C: Horizon H2 to the dataset's depth limit

These units are shown in Figure 2.

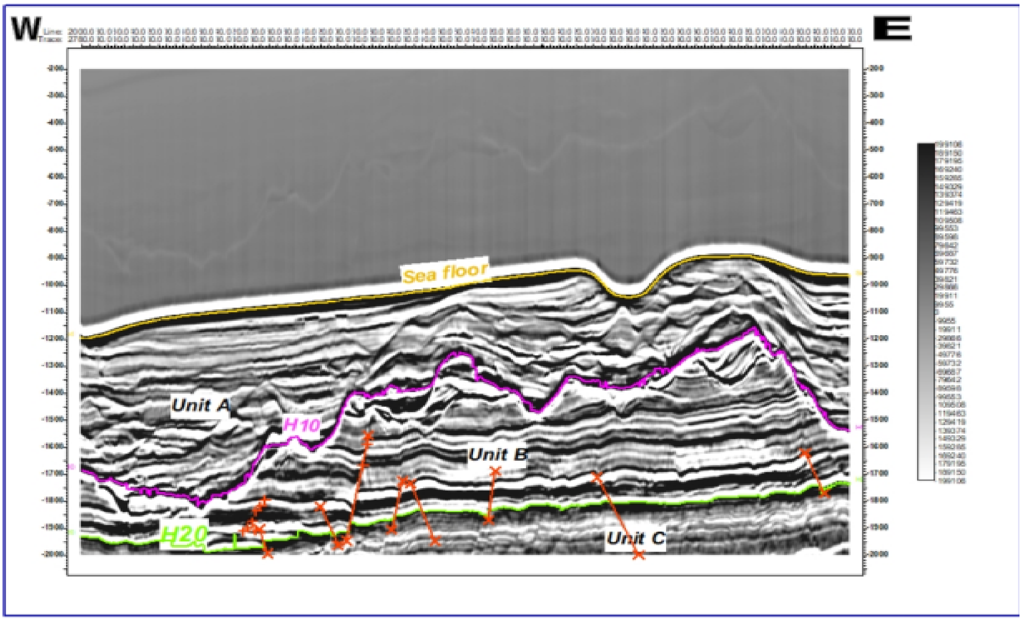

Figure 2: Crossline showing various units

Analytical Approaches

Structural Mapping:

- Fault delineation
- Unconformity identification
- Sedimentary feature classification

Amplitude Analysis:

- High-amplitude anomaly evaluation
- Bright spot identification
- Polarity reversal assessment

Seismic Attribute Analysis

Multiple attribute analyses were performed to enhance feature detection:

1. Amplitude-Based Attributes

- Root Mean Square (RMS) amplitude extractions (IHS Kingdom 2017 Software Manual, 2017). The amplitude extractions aid in the assessment and identification of potential shallow gas and fault planes

- Trace Envelope: Used for bright spot and gas-charged sediment identification, calculated as: $\mathcal{E}(z) = \sqrt{f^2(z) + g^2(z)}$ (IHS Kingdom 2017 Software Manual, 2017). represents the total instantaneous energy of the complex trace independent of the phase and is computed as the modulus of the complex trace.
- Instantaneous frequency

2. Structural Attributes

- Dip of Maximum Similarity: Applied for fault and seabed gradient visualization (IHS Kingdom 2017 Software Manual, 2017).
- Coherency

3. Lithological Indicators

- Shale Indicator: Used for lithological differentiation (IHS Kingdom 2017 Software Manual, 2017).

Hazard Classification and Analysis

Shallow Gas Classification

Quantitative classification criteria:

- Widespread: >50%
- Numerous: 30-50%
- Several: 15-30%
- Occasional: <15%

Risk Categories

Hazards were categorized as:

- **Slight Risk:** Minor anomalies with localized impact
- **Moderate Risk:** Widespread anomalies affecting operations
- **High Risk:** Zones requiring operational avoidance

Key Hazard Indicators

1. Shallow Gas:

- High-amplitude anomalies
- Reversed polarity
- Phase shifts

2. Faults:

- Displacement characteristics
- Dip similarity patterns

3. Seabed Instability:

- Gradient analysis (>14°)
- Canyon feature identification

Limitations and Assumptions

1. Depth Range Limitations:

- Analysis confined to shallow subsurface intervals
- Potential deeper hazards not captured

2. Interpretation Constraints:

- Auto-tracking efficiency benefits
- Manual validation requirements

Interpolation accuracy dependencies

RESULTS AND DISCUSSION

Seabed Conditions

From the seismic interpretation, seabed maps were produced as shown in Figure 3, 4 and 5 present; depth from sea level to the seabed in meters, a dip/seabed gradient profile, and an amplitude extraction map of the seabed, respectively. The seabed area covers an area of 148.687 km^2.

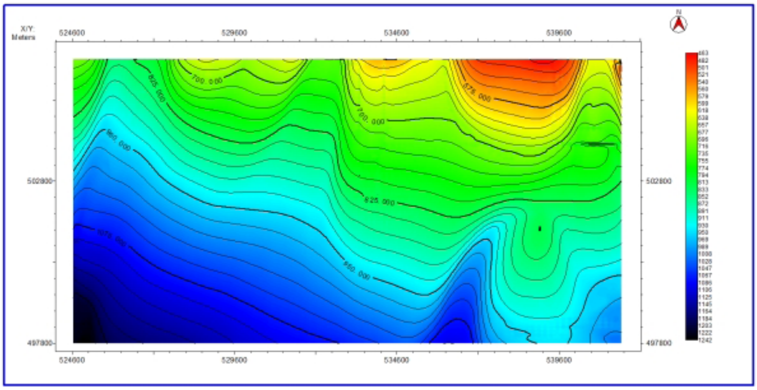

Figure 3: Depth/morphology map of seafloor

Figure 4 Seafloor visualisation highlight dips and slopes

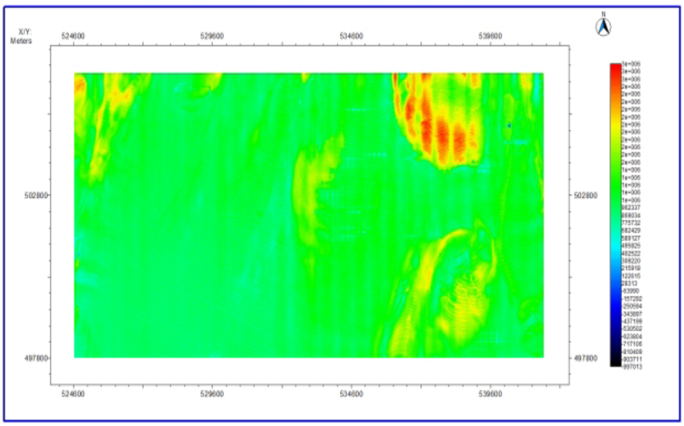

Figure 5: Amplitude extraction map of the seabed

The seabed depth ranges from 463 m in the northeast to 1,242 m below mean sea level in the southwest. Seabed generally deepens from north to south, with the greatest gradient being from northeast to southwest except within the seabed canyons where water depths deepen into the thalwegs. Gradients generally average 3° across the regions of the study area and are not affected by canyons. Seabed gradients generally ranging from 3° to 14° and occasionally up to 19° are located on the flanks of the seabed canyons as seen in Figure 4. The seabed within the study area shows seabed canyons in the east, north and northwest. A north-to-south trending seabed canyon occurs in the eastern part of the study area (Figure 4) ranging in width from 1.407 km in the north to at least 2.51 km in the south with a branching tributary trending NNE to SSW.

The seismic data does not clearly indicate any significant activity in the present seabed morphology within the channel even though there is the likelihood it might have been active in the past. This channel is at least presently seasonally active. Some other seabed canyons occur in the northeast measuring 2.6 km in diameter (Figure 6) and 1.6 km in diameter both opening out in the basin-ward direction towards the south. No other major morphological changes, catastrophic seabed failures, seabed fault intersections or interpreted hydrocarbon seepage were observed. Seabed amplitudes are generally low, consistent with seabed soil drape, while several areas within the canyon exhibit minor increased amplitudes. These amplitude variations are possibly due to slight changes in sediment composition and firmness and not considered anomalous. Seabed amplitudes are presented in Figure 6.

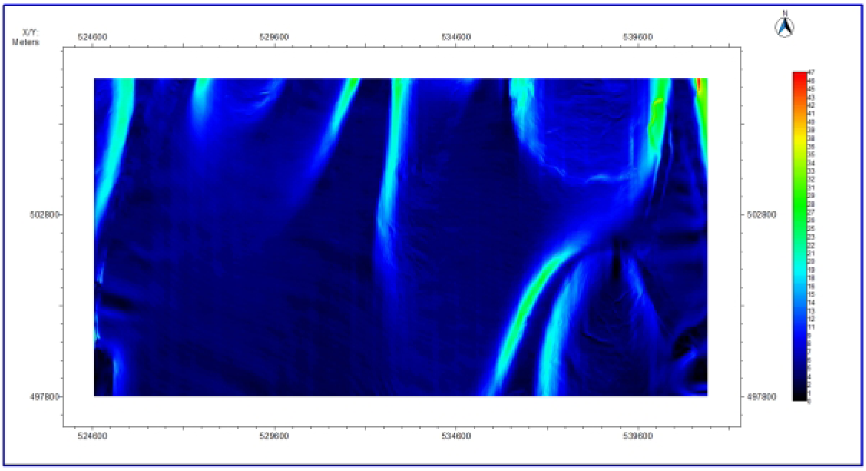

Figure 6: Seabed gradient map highlighting areas of relatively high gradient

Sub-Surface Conditions

Twelve maps have been produced from seismic interpretation of horizons and structures to understand the subsurface geology of the study area. A map that represents the depth to the seabed in meters below the sea surface has been generated for each horizon, a dip/seabed gradient map and an amplitude extraction map of the units as well.

The subsurface of the survey area goes to a depth of 2 km below mean sea level.

Unit A

Unit A is defined as the interval between Seabed and Horizon H1. An amplitude extraction for this interval is presented in Figure 7 while a trace envelope seismic extraction on the amplitude is presented in Figure 8.

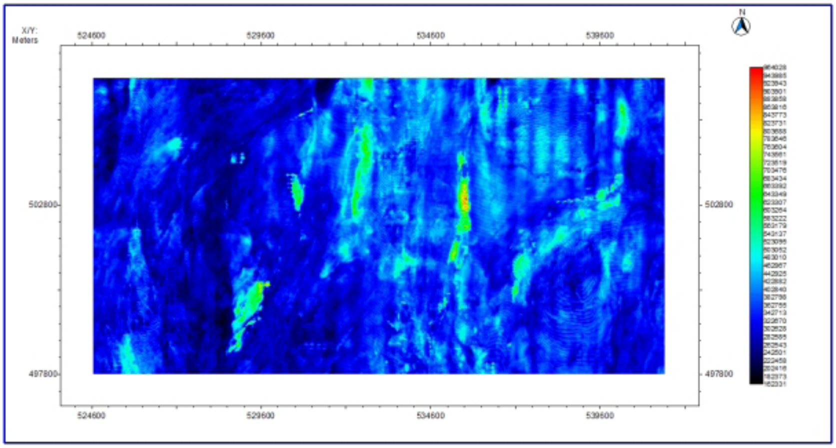

Figure 7: RMS amplitude extraction for Unit A

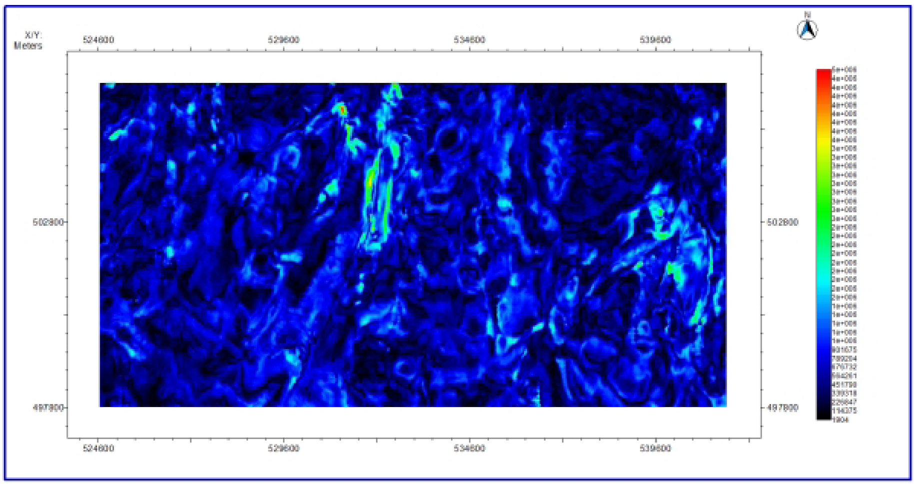

Figure 8: Trace Envelope seismic attribute analysis for Unit A

These higher amplitudes (as shown earlier in Figure 6) can be observed from Figure 8 to not be anomalous, and are perhaps lithological in nature. Figure 9 is a map showing the morphology of seabed canyons.

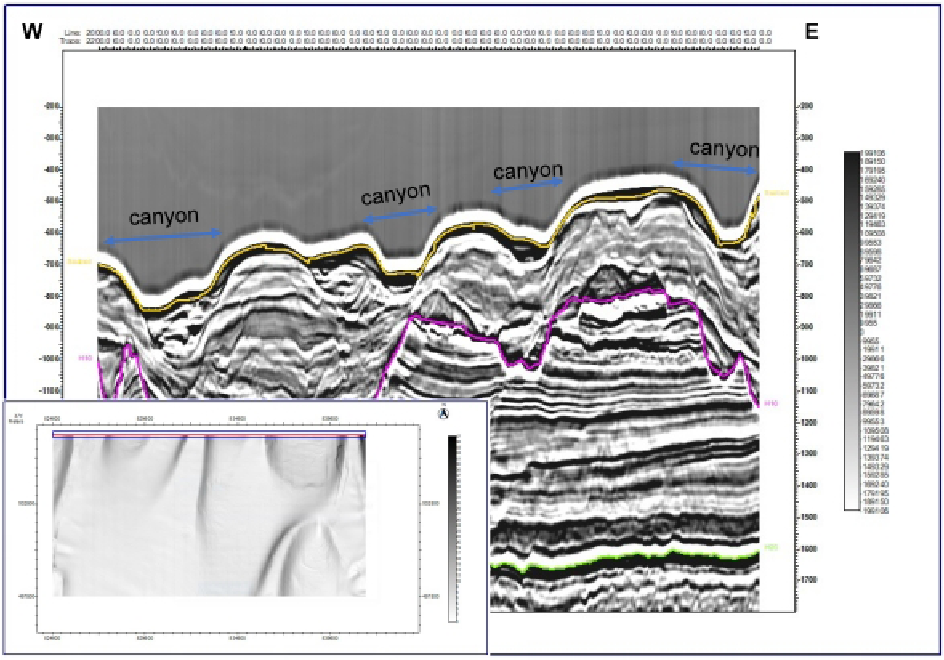

Figure 9: Morphology of Seabed Canyons

Some localized areas where the anomalous response exceeds four times the background amplitude levels are hence considered anomalous. Minor diffused shallow gas accumulations could be present (Figure 8), and these areas are assigned a Slight Risk of Gas. Unit A has no interpreted or observed faults. Figure 10 is an amplitude extraction of Unit A using seismic attributes where low values indicated as blue regions represent sandstones and carbonates and higher values are representative of shales or shaly rocks.

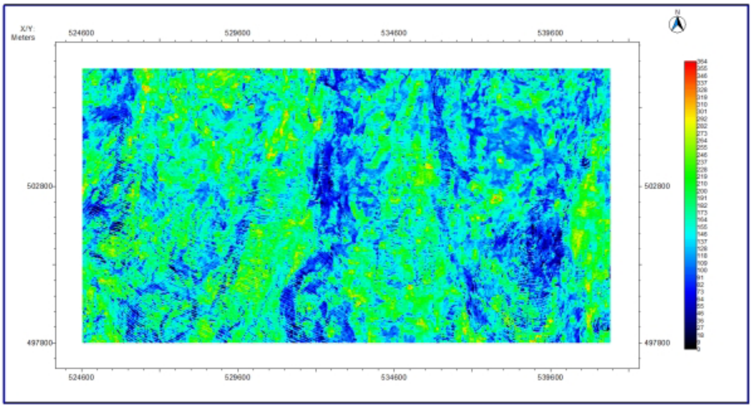

Figure 10: Shale indicator map for Unit A

It can be noted then that the rock units in Figure 10 show numerous sandstone areas with values of around 64–100 and widespread shaly minerals, possibly marlstones, generally ranging from 100 to 280 with tiny spots of very high values, possibly shales or mudstones. Sandstones may cause minor wellbore instability and drilling fluid circulation problems.

Horizon H1

Figure 11 is the depth map of the interpreted horizon H1 with depths ranging from -768 m in the northeast to -1885 m in the southwest.

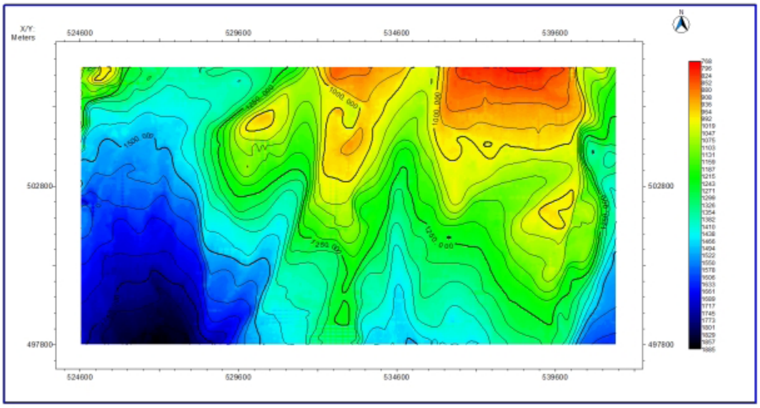

Figure 11: Depth/morphology map for horizon H1

The horizon is identified to be an unconformity event which is regional and most probably the Oligocene-Miocene unconformity (Fuentes, 2019) and hence a very likely area for gas accumulations. Figure 12 is a seismic section of the data volume indicating evidence of nonconforming reflectors in unit B. The nonconforming reflectors can clearly be seen in Figure 13.

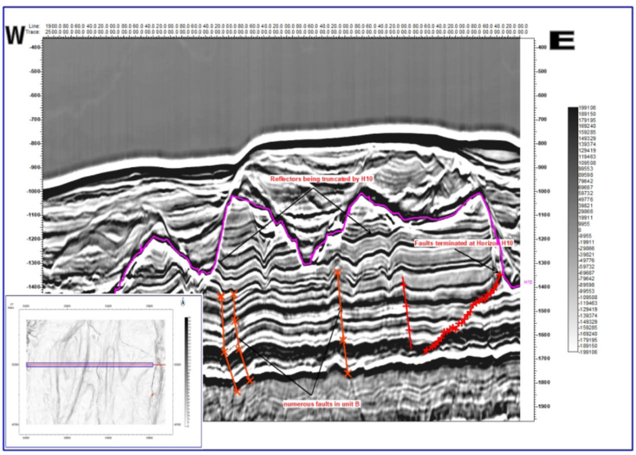

Figure 12: Evidence of unconformity in H1

Occasional high amplitude anomalies, possibly related to shallow gas accumulations, are scattered throughout the study area. These anomalies exhibit an increase in amplitude with no other characteristics consistent with shallow gas (Figure 13 is a Trace Envelope seismic attribute map of Horizon H1). As such, they have been assigned a “Slight Risk of Gas” and are shown in Figure 13 as green to red regions on the map.

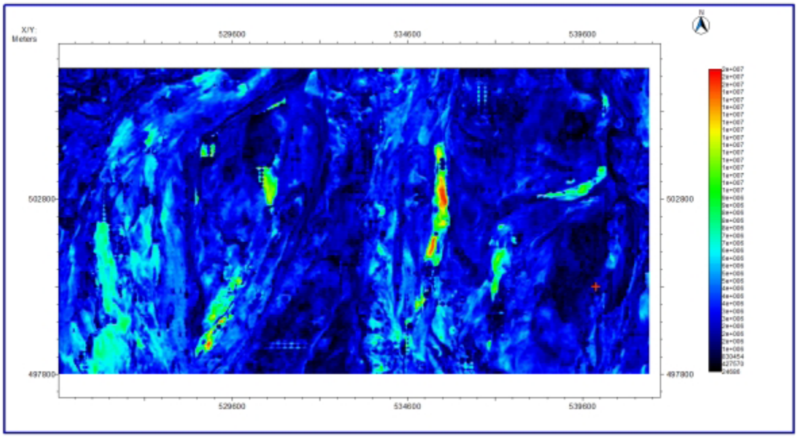

Figure 13: Trace Envelope seismic attribute analysis for H1

At Horizon H1, several complex faults intersect or terminate. The faults, if traversed, may cause minor wellbore instability and drilling fluid circulation problems. Most of these faults are also encountered in Unit B, and their risks are discussed in detail then. Figure 14 is a seismic attribute extraction for horizon H1, indicating various lithologies at that horizon.

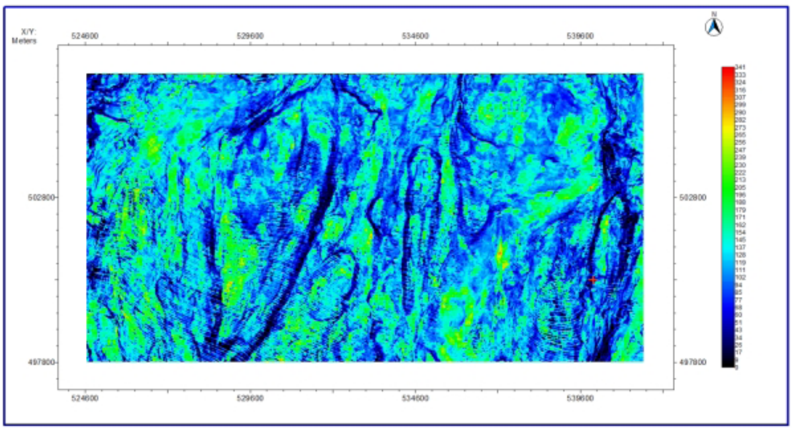

Figure 14: Shale indicator map for horizon H1

Dark blue regions indicating sandstones and carbonates are found to be in the thalwegs of ancient, buried channels in the horizon. Occasionally, these exhibit additional characteristics indicative of shallow gas (Figure 13), mainly anomalous amplitudes, and hence are assigned only a slight risk of gas. The interpreted sands located within the buried channels present the character of deposition in a slightly higher-energy environment with inadequate time for dewatering before being buried with a clay-prone seal (in Unit A) (Fuentes, 2019).

Unit B

Figure 15 is the shale indicator map for Unit B.

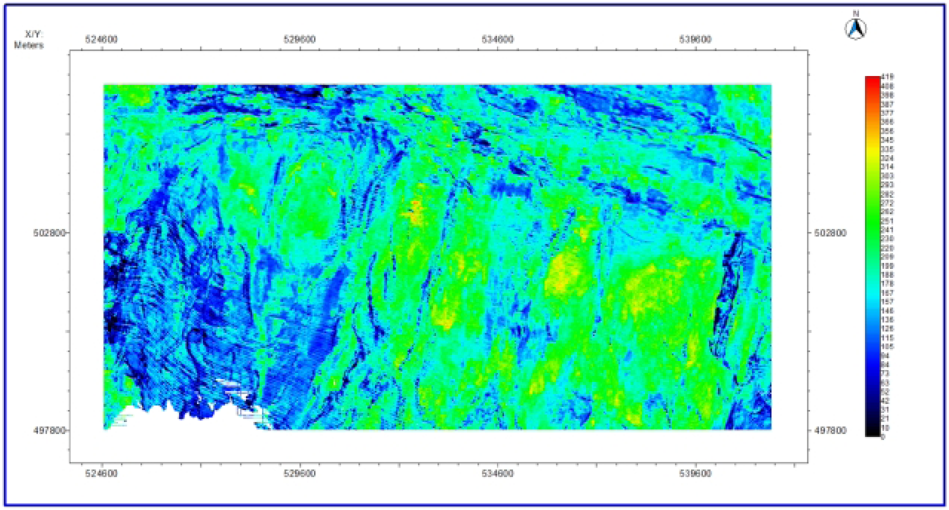

Figure 15: Shale indicator map for Unit B

A region of low to mid-low values is located in the NNW, northeast, southeast, and southwest, and these are related to thick sandstone or marlstone interbeds located in the upper part of Unit C and likely related to erosional processes that affect the lower part of Unit A and the Miocene Unconformity (Horizon H1). Most of the anomalies only exhibit an increase in amplitude with no other characteristics consistent with shallow gas. Some occasionally show additional characteristics such as slight masking of the underlying sediments and phase reversal.

As such, these anomalies within Unit B have been assigned a “Slight” and “Moderate Risk of Gas”, dependent on the characteristics exhibited by the specific anomaly. Predicted sands within Unit B are presented in Figure 15 as blue regions.

The complex faults that traverse Unit B may cause minor wellbore stability and drilling fluid circulation problems if contacted. The largest of these faults occur within the northeastern part of the study area and have been labelled F1, F2, F3, and F4, as seen in Figures 16 and 17, each having average throws of 40 m, 20 m, 100 m, and 70 m, respectively, and should therefore be avoided. Other widespread faults occur and can also pose challenges and thus have only been assigned a “Slight Risk of Gas.”

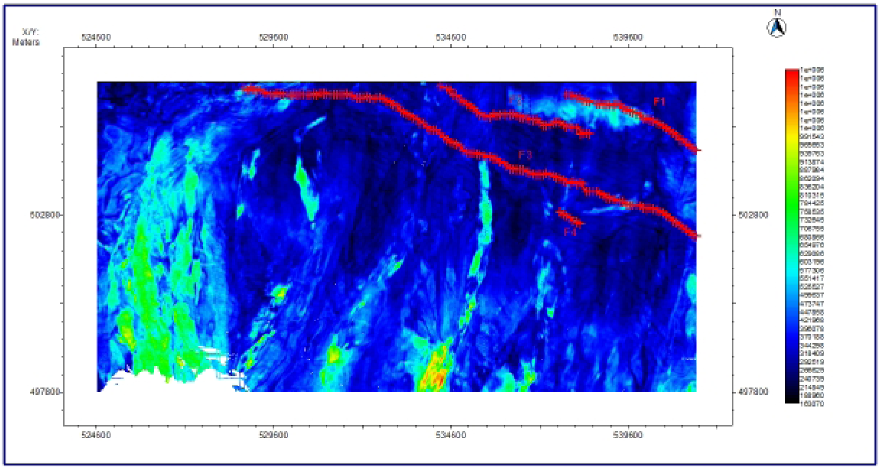

Figure 16: Dip similarity map showing the trends of major faults in Unit B

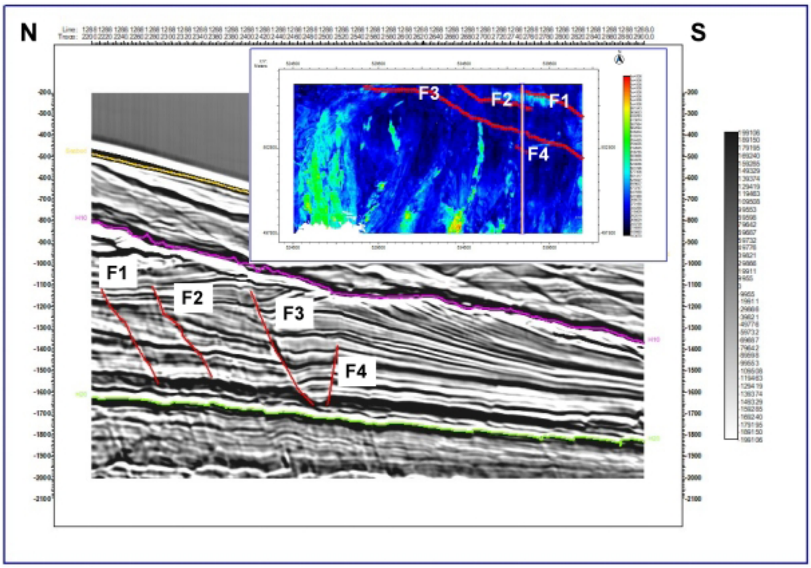

Figure 17: Seismic Inline showing major interpreted faults in section

Horizon H2

Horizon H2 begins at a depth of 1600 m subsea in the northeast and northwestern parts of the study area and deepens to a depth of 2000 m subsea towards the southwestern parts of the area (Figure 18).

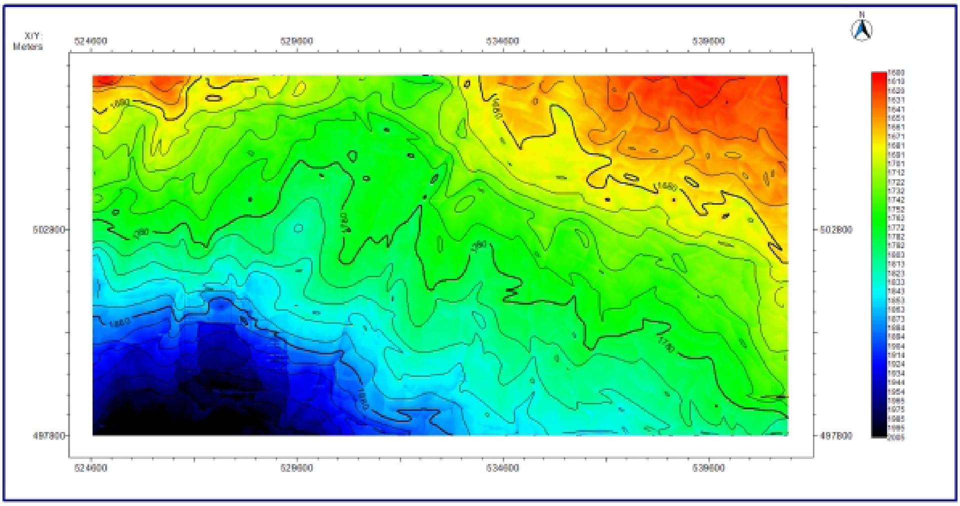

Figure 18: Depth/morphology map of H2

The amplitude extraction at H2 illustrates several higher amplitudes in the west part of the study area associated with possible sands or thin marls that are associated with a thin interval at the level of the horizon exhibiting a slightly channelized character (Figure 19).

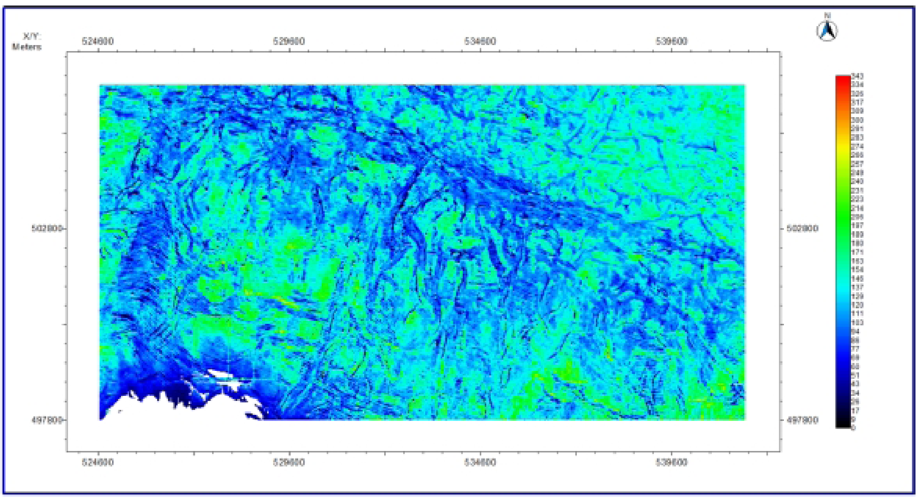

Figure 19: Shale indicator map for H2

The anomalies only exhibit an increase in amplitude with no other characteristics consistent with shallow gas and have been assigned a "Slight Risk of Gas". The sands and coarser interbeds may cause minor wellbore and drilling fluid circulation problems. Interpreted sands at the level of Horizon H2 are shown in Figure 15. Several complex, often polygonal, character faults are interpreted to intersect Horizon H2 (Figure 20).

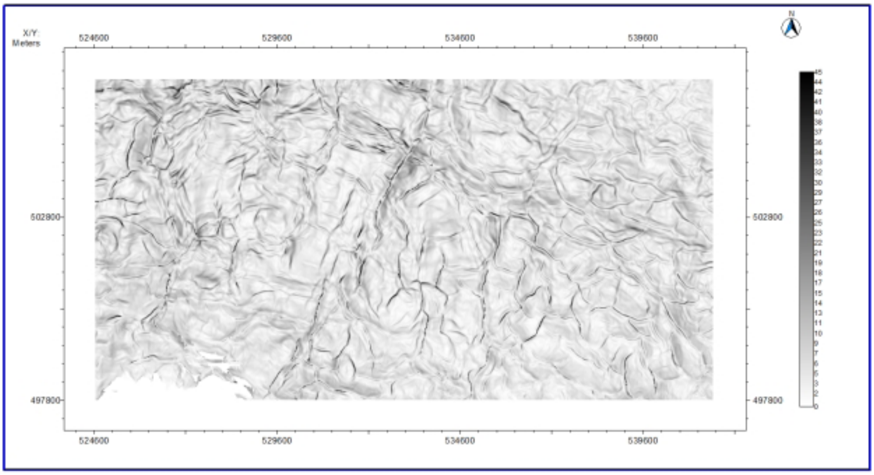

Figure 20: Dip similarity map for H2

The faults, if traversed, may cause minor wellbore and drilling fluid circulation problems.

Unit C

Unit C is defined as the interval between Horizon H2 to -2000m subsea the limit of the data set. An RMS amplitude extraction for this interval is presented on Figure 21

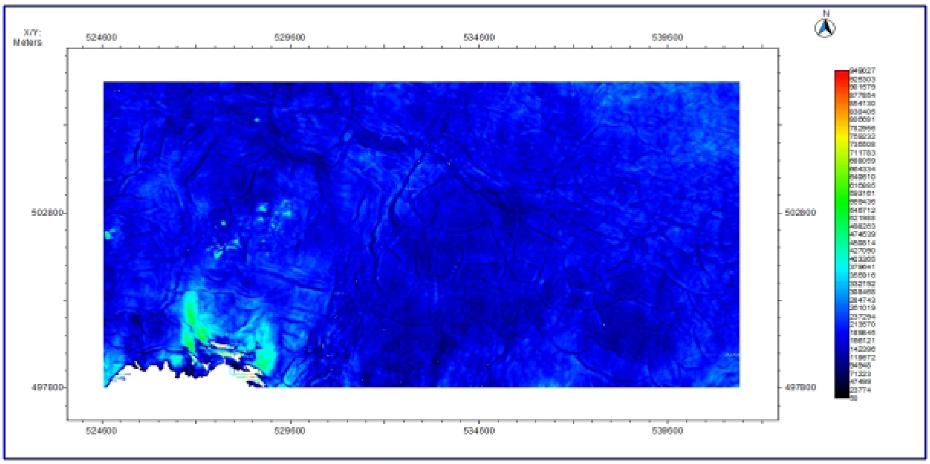

Figure 21: RMS amplitude extraction for Unit C

The amplitude extraction for Unit C shows occasional high amplitudes scattered across the north of the study area. These anomalous amplitudes are interpreted as sands but do not exhibit characteristics consistent with shallow gas. The sandstones (Figure 22), however, may cause minor wellbore stability and drilling fluid circulation problems. Several complex and often polygonal character faults traverse Unit C (Figure 21). The faults if traversed may induce minor wellbore stability and drilling fluid circulation problems.

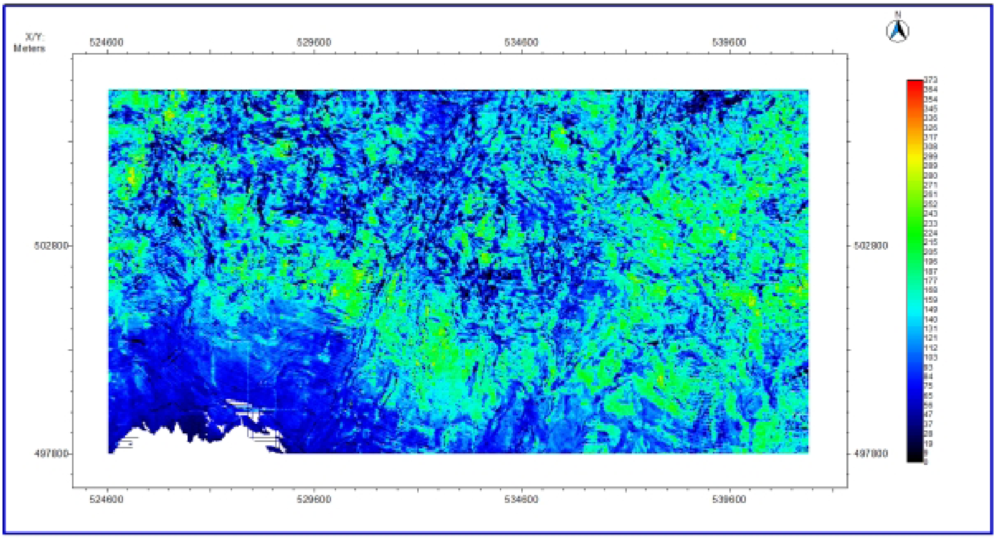

Figure 22: Shale indicator map for Unit C

KEY FINDINGS AND IMPLICATIONS FOR DRILLING

The findings of this study focused on geohazards in the Tano Basin, align with and extend existing knowledge of offshore drilling hazards. Offshore geohazards, as defined by Kvalstad (2007), encompass geological and geomorphological features that present risks during exploration and production, including shallow gas accumulations, fault zones, and unstable seabed conditions. These hazards can compromise wellbore stability, equipment functionality, and overall safety.

This study's identification of shallow gas accumulations and fault zones in Units A and B, and their correlation with the Oligocene-Miocene unconformity (Horizon H1), is consistent with findings in similar transform margin basins. For instance, Chiocci *et al*. (2011) highlighted that unconformities often serve as traps for shallow gas, posing significant blowout risks. Similarly, gas chimneys and shallow accumulations, commonly observed in the Gulf of Guinea (Delteil et al., 1974), were also detected in the Tano Basin. These features, coupled with steep seabed gradients in canyon regions, underscore the high susceptibility of the study area to mass movements and structural instability (Ercilla *et al*., 2021).

Gas hydrates and shallow gas, documented as primary offshore hazards by Wang *et al*. (2018) and Floodgate & Judd (1992), were not explicitly identified in this study. However, the slight risks of gas indicated in the amplitude anomalies of Unit A and Horizon H1 reflect the potential for localised drilling challenges. Shale instability, a common issue during drilling in offshore environments, was observed as well, in alignment with mechanical and chemical failure modes outlined by Nmegbu & Ohazuruike (2014).

The steep flanks of the north-south trending seabed canyon present a clear risk of mass wasting, consistent with the slope instability hazards described by NGI (2003). Avoiding these areas during well placement is critical. Additionally, the study's findings on fault dynamics align with Machado's (2020) emphasis on the role of seismic attributes in understanding fault behaviour and mitigating drilling fluid circulation problems.

Recommendations from previous studies suggest that the best mitigation strategy for geohazards is avoidance (Tierra Group International, 2022). However, in scenarios where avoidance is impractical, adaptive measures such as real-time seismic monitoring and advanced well design may be necessary to mitigate risks, as suggested by Chiocci *et al*. (2011).

CONCLUSIONS

This study assessed shallow drilling hazards in the Tano Basin, offshore Ghana, to identify safe locations for well placement and improve drilling safety. Utilizing high-resolution 3D seismic data, the analysis revealed critical geohazards, including seabed canyons, faults, and shallow gas accumulations. Key findings include:

- North-south trending seabed canyons with steep flanks prone to sliding failures, potentially compromising wellbore stability.
- Isolated anomalies and shallow gas accumulations in Unit A, indicating minor risks to drilling operations.
- Horizon H1 as a major unconformity with shallow gas risks and fault zones that could cause wellbore instability and fluid circulation challenges.
- Unit B as the most hazardous interval, hosting significant gas accumulations and faults, which pose moderate to high risks to safe well placement.
- Interpreted sandstones and coarser interbeds across various horizons, which may induce minor mechanical failures and fluid circulation issues.

These findings emphasize the importance of avoiding high-risk areas, such as fault zones, gas-prone regions, and seabed canyons, during well placement. Future research should focus on real-time monitoring techniques to predict geohazards dynamically and improve mitigation strategies in offshore drilling environments.

Declaration of Conflict of Interest

The authors declare no conflicts of interest associated with this publication.

REFERENCES

Atta-Peters, D. (2014). Source rock evaluation and hydrocarbon potential in the Tano Basin, South Western Ghana, West Africa. *International Journal of Oil, Gas and Coal Engineering*, 2(5): 66.

Bempong, F.K., Ozumba, B.M., Hotor, V., Takyi, B., Nwanjide, C.S. (2019). A review of the geology and the petroleum potential of the Cretaceous Tano Basin of Ghana. *Journal of Petroleum Environmental Biotechnology*, 10: 395.

Bingyin, W., Jingen, D., Jianliang, Z., Yanfeng, C., Lingzhan, Z. (2006). Numerical simulation of undergauging deformation behavior of horizontal wells in unconsolidated sandstone reservoirs. *Natural Gas Industry*, 26(5): 55-57.

Bowes, C., Procter, R. (1997). *Drillers Stuck Pipe Handbook*. Ballater, Scotland: Procter & Collins Ltd.

Brownfield, M.E., Charpentier, R.R. (2006). Geology and total petroleum systems of Gulf of Guinea Province of West Africa. *US Geological Survey Bulletin*, 2207-C: 32.

Chen, X., Tan, C.P., Haberfield, C.M. (2002). A comprehensive, practical approach for wellbore instability management. *SPE*

Drilling & Completion, 17(4): 224-236.

Chiocci, F.L., Cattaneo, A., Urgeles, R. (2011). Seafloor mapping for geohazard assessment: State of the art. *Marine Geophysical Research*, 32(1): 1-11.

Cox, D.R. Newton, A.M.W., Huuse, M. (2020b). An introduction to seismic reflection data: acquisition, processing and interpretation. N. Scarelli, J. Adam, D. Chiarella (Eds.), Regional geology and tectonics – principles of geologic analysis, Elsevier, Amsterdam, pp. 571-603

Delteil, JR., Valery, P., Montadert, L., Fondeur, C., Patriat, P., Mascle, J. (1974). Continental Margin in the Northern Part of the Gulf of Guinea. In: Burk, C.A., Drake, C.L. (eds) The Geology of Continental Margins. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-01141-6_22

Ercilla, G., Casas, D., Alonso, B., Casalbore, D., Galindo-Zaldívar, J., García-Gil, S., Martorelli, E., Vázquez, J.-T., Azpiroz-Zabala, M., DoCouto, D., Estrada, F., Fernández-Puga, M. C., González-Castillo, L., González-Vida, J. M., Idárraga-García, J., Juan, C., Macías, J., Madarieta-Txurruka, A., Nespereira, J., ... Yenes, M. (2021). Offshore Geological Hazards: Charting the Course of Progress and Future Directions. Oceans, 2(2), 393-428. https://doi.org/10.3390/oceans2020023

Floodgate, G.D., Judd, A.G. (1992). The origins of shallow gas. *Continental Shelf Research*, 12(10): 1145-1156.

Fuentes, L. (2019). Interpretation report for Springfield Exploration and Production Limited.

Giles, D.P., Griffiths, J.S. (2020). Geological hazards in the UK: Their occurrence, monitoring and mitigation – Engineering Group Working Party Report. *Geological Society, London, Engineering Geology Special Publications*, 29(1): 1-41.

Herron, D.A. (2013). First steps in seismic interpretation. In R.B. Latimer (Ed.), *Learning Disability Practice*, 16(7).

Johnson, W., Calarco, M., Zolezzi, F. (2014). Offshore geohazards industry implications and geoscientist role. 1st Applied Shallow Marine Geophysics Conference, Near Surface Geoscience 2014: 14-48.

Kvalstad, T.J. (2007). What is the current "best practice" in offshore geohazard investigations? A state-of-the-art review. *Offshore Technology Conference*, OTC-18545-MS.

Liu, L., Chu, F., Wu, N., Zhang, L., Li, X., Li, H., Li, Z., Zhang, W., Wang, X. (2022). Gas Sources, Migration, and Accumulation Systems: The Shallow Subsurface and Near-Seafloor Gas Hydrate Deposits. Energies, 15(19), 6921. https://doi.org/10.3390/en15196921

Machado, G. (2020). A simple guide to seismic horizon interpretation. *Geoscience Magazine GEO ExPro*, 17(6): 42-48.

Malehmir, A., Socco, L. V., Bastani, M., Krawczyk, C. M., Pfaffhuber, A. A., Miller, R. D., Maurer, H., Frauenfelder, R., Suto, K., Bazin, S., Merz, K., Dahlin, T. (2016). Near-Surface Geophysical Characterization of Areas Prone to Natural Hazards: A Review of the Current and Perspective on the Future. Advances in Geophysics, 57, 51-146. https://doi.org/10.1016/bs.agph.2016.08.001

Mark, N., Schofield, N., Pugliese, S., Watson, D., Holford, S.P., Muirhead, D.K., Brown, R.J., Healy, D. (2017). Igneous intrusions in the Faroe Shetland basin and their implications for hydrocarbon exploration; new insights from well and seismic data. Marine and Petroleum Geology, 92, 733-753.

McLellan, P.J. (1996). Assessing the risk of wellbore instability in horizontal and inclined wells. *Journal of Canadian Petroleum Technology*, 35(5).

Mohiuddin, M., Awal, R. Abdulraheem, A. Khan, K. (2001). A New Diagnostic Approach to Identify the Causes of Borehole Instability Problems in an Offshore Arabian Field. 10.2523/68095-MS.

Nmegbu, G., Ohazuruike, L. (2014). Wellbore instability in oil well drilling: A review. *International Journal of Engineering Research*, 10(5): 11-20.

Rijks, E.J.H., Jauffred, J.C.E.M. (1991). Attribute extraction: An important application in any detailed 3-D interpretation study. *The Leading Edge*, 10(9): 11-19.

Rossetti, D.F., Bezerra, F.H.R., Dominguez, J.M.L. (2013). Late Oligocene–Miocene transgressions along the equatorial and eastern margins of Brazil. *Earth-Science Reviews*, 123: 87-112.

Rüpke, L. H. , Schmid, D. W., Hartz, E. H., Martinsen, B. (2010) Basin modelling of a transform margin setting: structural, thermal and hydrocarbon evolution of the Tano Basin, Ghana. Petroleum Geoscience, 16 (3). pp. 283-298. DOI 10.1144/1354-079309-905.

Strasser, M., Hilbe, M., Anselmetti, F.S. (2011). Mapping basin-wide subaquatic slope failure susceptibility as a tool to assess regional seismic and tsunami hazards. *Marine Geophysical Research*, 32(1): 331-347.

Taner, M.T., Sheriff, R.E. (1977). Application of amplitude, frequency, and other attributes to stratigraphic and hydrocarbon determination. In C.E. Payton (Ed.), *Seismic Stratigraphy — Applications to Hydrocarbon Exploration*, 26: 301-327.

Tetteh, J.T. (2016). The Cretaceous play of Tano Basin, Ghana. *International Journal of Applied Science and Technology*, 6(1): 1-10.

Wang, F., Zhao, B., Li, G. (2018). Prevention of potential hazards associated with marine gas hydrate exploitation: A review. *Energies*, 11(9): 2384-2403.